THE GEOLOGY AND PALEONTOLOGY OF THE CRETACEOUS DEPOSITS OF MEXICO.

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In the following pages I have attempted to present, so far as they are known to me, all the leading facts touching the geological and paleontological relations of the Cretaceous deposits of Mexico. It is true these are still far from sufficient to permit us to analyze with satisfaction the minor details of the geology of so vast a region as the Mexican Republic, but they serve to clearly mark out its more salient geognostic features, and to establish its relationship with the great continental mass lying to the north and with the oceans which bound it on the east and on the west. My own observations were made in the spring of the present year (1890), when, as chief of the scientific expedition organized under the auspices of the Academy of Natural Sciences of Philadelphia, I traversed much of the south-central region of the Republic, from the Atlantic nearly to the Pacific, at the same time that I enjoyed the opportunity of studying special collections which had been previously made at points not reached by our party.

The conclusions stated in the present paper are the following:

1. Cretaceous deposits cover, or are scattered over, the greater part of Mexico, from the Atlantic plains to the Pacific, and from the Rio Grande to (or through) the States of Colima, Michoacan, Guerero and Oaxaca. These deposits are continuous with the Cretaceous area of the interior basin of the United States, and are largely the equivalents in age of the deposits which are represented in Texas and in the other Gulf States.

2. The Mexican Cretaceous deposits that have thus far been identified by fossil remains represent a horizon not lower than the Cenomanian, while the greater bulk of the formation is of Turonian or Senonian age. The deposits are thus a part of the Middle (?) and Upper Cretaceous series of the true geological scale.

3. No unequivocal deposits of Lower Cretaceous age—as equivalents of the Gault, Neocomian, etc.—have yet been discovered in the Republic, although some such may exist intermingled with, or underlying, the newer series.

4. The great central plateau of Mexico consists in greater part of nuclear Cretaceous strata, over whose uneven summits a more or

less even surface has been prepared through aqueous erosion (and sedimentation) and long-continued volcanic discharges, principally the latter. Along the southern margin of the plateau the Cretaceous strata (emerging from the plateau) rise to an absolute elevation (above the sea) of upwards of 8,000 feet.

5. The Cretaceous rocks, which form the nucleus of the plateau, are projected (with little diminution in height) in more or less parallel ridges southward from the southern scarp of the plateau, proving that the plateau uplift is not due to faulting on the east and west line which marks the positions of the principal volcanic summits of the Republic.

6. The Gulf plain of Mexico has been largely formed through down-wash from the interior heights, but low-level limestones (with little doubt of Cretaceous age) appear in places beneath the capping of volcanic sand and boulders. Marine Tertiary strata seem to be restricted to the northern portion of the Gulf plain, and to point off rapidly after leaving the Rio Grande. No marine Tertiary strata are known from the plateau region.

7. The Cretaceous sea swept continuously across the Republic from what is now the Gulf border to the Pacific, but strips or islands of Azoic and Palæozoic rock probably projected from this sea, much as the peninsula of Lower California and the neighboring islands to-day project from the Mexican Pacific.

9. No true Lower Cretaceous beds exist (or have been so far identified) in either Texas or Arkansas, the Lower Cretaceous, so-called (Comanche series, etc.), being not older than the Cenomanian (Middle or Upper Cretaceous).

9. No marine deposits of unequivocally Lower Cretaceous age have thus far been determined in the United States east of the Rocky Mountains.

The earliest recognition of the existence of Cretaceous deposits in Mexico is, I believe, contained in Galeotti's paper "Notice sur le calcaire crétacé des environs de Jalapa au Mexique," published in the tenth volume of the Bulletin de la Société Géologique de France (pp. 31–39, 1839). Remarkably enough, this paper, although prepared with much care and considerable detail, has been very generally overlooked by geologists, but in it the author strikes the keynote to the geology of the greater part of the Republic. Galeotti's researches cover various outcrops ("islets") of white, cream and

blue limestones, which he locates as follows:—of Songuantla, at the elevated base of the Cofre de Perote, two and a half leagues from Jalapa; the *barranca* (ravine) of Gilotepec, 4 leagues N. N. E. of Jalapa; the *hacienda* of Tusamapa; the *barranca* of Jalcomulco, S. S. E. of Jalapa. These various outcrops, which in a general way are said to trend W. N. W.—E. S. E. or W. by N.—E. by S., with a steep pitch southward or southwestward, are on paleontological grounds referred to a single horizon, which is considered to be the partial equivalent of Dufrénoy's Cretaceous of southern France. This determination rests on the discovery in the rocks of fragments of *Ammonites*, *Ostrea*, *Pecten*, *Cardium* and *Lucina*, and of various foraminiferal forms (*Miliola*, *Nodosaria*, *Nummulina*).

I strongly suspect that what are here referred to as fragments of oysters are in part, at least, the remains of *Hippuritidæ*. These are abundant in the limestone of Coatepec, of the same region, which I examined, but I failed to find in that rock any true oysters; however, this is only negative testimony. The Hippuritidæ there occurring are sufficient evidence of the correctness of Galeotti's reference. Less reliable, probably, is Galeotti's determination of his assumed Nummulite, which he describes as *Nummulina Songuantlæ* (p. 35.) No undoubted member of this group of organisms has thus far been found in any Cretaceous deposit, and it is likely that the present reference rests on an erroneous interpretation of the fossil in question. Galeotti's figure (Bulletin, Plate X, fig. 6) can scarcely represent a Nummulite, and, indeed, he himself compares it with *Nummulina lenticula*, presumably of Defrance, which is now known to be an *Amphistegina*. D'Archiac is probably correct in referring the species to the genus *Cristellaria*.[1]

In the year following the publication of the paper above mentioned appeared a joint paper by Nyst and Galeotti "Sur quelques fossiles du calcaire jurassique de Tehuacan, au Mexique.[2]" The authors describe a number of fossils from a locality in the "Cordillère d'Anahuac," some 12 leagues W. N. W. of Tehuacan, and from an elevation of some 4000–7000 feet above the sea. The region is one of gray and brown limestones, and said to be exceedingly rich in organic remains. Indeed, it is questioned whether there exists another region

[1] Description des Animaux Fossiles du Groupe Nummulitique de l'Inde, pp. 36 and 163.

[2] Bulletin de l'Académie Royale des Sciences de Bruxelles, VII, 1840, pp. 212–21.

on the earth's surface which in an equal area abounds so largely in fossil remains (p. 220). The abundance of fragments of large Ammonites, supposed to measure from 50 to 60 centimetres in diameter, is especially commented upon.

With due deference to the learning and experience of the authors, I am constrained to believe that the formation in question is not of Jurassic age, but Cretaceous, and I may add, late Cretaceous. It is true, I have not been in the precise region described by Nyst and Galeotti, but my observations extend around and about it in various directions, and I have nowhere in the limestone region found any good indications of Jurassic fossils. Cretaceous forms, on the other hand, are very abundant, and just in the mountains of Tehuacan do they appear in great numbers. Furthermore, the fossils of Tehuacan, from the region of the large quarries of Mexican onyx, are almost precisely identical with those (*Hippurites*, *Radiolites*, etc.) which I have seen in the limestones of Coatepec (Jalapa), of Atoyac, the Cerro de Escamela, near the town of Orizaba, of Apasco, Yautepec, Coalcoman (in Michoacan), etc., showing the broad extent of an identical formation. Nyst and Galeotti in the memoir above cited describe twelve species of fossils—*Trigonia plicato-costata*, *Ostrea acuticosta*, *O. similis*, *Cerithium suturosum*, *C. Bustamentii*, *C. cingulatum*, *Terebra minuta*, *Ammonites Rioii*, *A. reconditus*, *Cidarites propinquus*, *C. pustulosus*, and *C. glandiferus*—and it is upon the supposed relationships of these that the reference to the Jurassic formation is made. *Cidarites propinquus* (Münster) and *C. glandiferus* (Goldfuss) are considered to be well-known species from the Jurassic deposits of Germany. The figures illustrating the above are apparently faithfully drawn, but I fail to find anything in them which would indicate that they deal with Jurassic, rather than with Cretaceous, fossils. *Trigonia plicato-costata*, which appears to be one of the most abundant of the fossils occurring in the region under consideration, represents a well-recognized Upper Cretaceous type of *Trigonia*, that of *T. alæformis* and *T. scabricola*, and is far removed from the distinctive Jurassic forms. Indeed, Nyst and Galeotti themselves recognize the relationship with the first-named, from which they distinguish it by the character of the costal ornamentation. While I am not certain that the Mexican species is really distinct, yet, in the absence of specimens for direct comparison, it may be well to consider it so. But I believe there can be no doubt as to the horizon which it represents. D'Orbigny, in his

Prodrome de Paléontologie,[1] has already corrected the error of Nyst and Galeotti, and transferred the species to the Upper Cretaceous horizon (his Senonien), where likewise it is placed by Lycett in his "Monograph of the British Fossil Trigoniæ."[2]

As regards *Ammonites Rioii*, which Nyst and Galeotti compare with *A. subradiatus* (Sowerby) and *A. complanatus* (Mantell)—the former a Jurassic species, and the latter first described from the Cretaceous marls of Sussex—there can be no question that the relationship is most intimate with the last named. *Ammonites subradiatus* is a distinctly carinated species, whereas the Mexican form has an evenly rounded dorsum. Again, *Ammonites reconditus* manifestly represents the type of *A. Duvalianus*, D'Orbigny, from the Cretaceous deposits of France,[3] and is in no wise a Jurassic form. D'Orbigny has correctly interpreted the aspect of the Mexican Ammonites by referring them to his Senonian horizon.[4]

I can speak with less certainty regarding the two species of sea-urchin which Nyst and Galeotti identify with *Cidarites propinquus* of Münster, and *C. glandiferus* of Goldfuss, since the drawings of the species are not sufficiently precise to permit of absolute determinations being made from them. But the form which, from the shape of its spines, is referred to *C. glandiferus*, appears to be at least as nearly related to the well-known Cretaceous *C. clavigera* of König, whose multiform spines are so largely scattered through the deposits of the Chalk. *Cidarites pustulosus* is probably a *Pseudodiadema*.[5]

The data that have here been given will probably be considered

[1] Vol. II, p. 240. No. 605.

[2] Palæontographical Society Reports (Fossil Trigoniæ), 1872–79, pp. 131 and 229.

[3] D'Orbigny, Paléontologie Francaise, Terrains Crétacés, Atlas, I, pl. 50, figs. 4, 5.

[4] Prodr. de Paléont., II, p. 214.

[5] Since the above was written I have received folios 16–20 of vol. XVIII (3rd series) of the Bulletin de la Soc. Géol. de France (1890), containing Cotteau's article: "Notes sur quelques Echinides du terrain Crétacé du Mexique." The author reviews the species described by Nyst and Galeotti, and finds their determinations erroneous. The form referred to *Cidarites propinquus* of Münster, is an altogether different species; the so-called *Cidarites glandiferus* is a *Pseudocidaris*, related to *P. clunifera* and *P. mammosa;* and *Cidarites pustulosus* is either *Pseudocidaris or Diplopodia* (related to *D.* [*Pseudodiadema*] *Malbosi*). Cotteau concludes, from the facies of the echinoid fauna, that the formation which it represents is Cretaceous, and not Jurassic (p. 293).

amply sufficient for relegating the mountain deposits of the region under consideration to the Cretaceous formation; and Gabb implies as much in a prefatory remark contained in his report on a collection of fossils from near Arivechi, State of Sonora.[1] In this report the author clearly establishes the existence of Cretaceous deposits in the northern part of the Republic, and draws attention to the close connection existing between the contained fossils and those from the Cretaceous of Texas. Much more marked, on the other hand, is the variation from the Californian fossils of approximately the same horizon.[2]

Mr. Gabb records the following fossils from the deposits of Arivechi:

Ammonites Pedernalis, Von Buch.—Species also occurring in the Cretaceous of Texas.
Fusus Mexicanus, Gabb.
Lunatia Pedernalis, Roemer.—Also found in Texas.
Euspira tabulata, Gabb.
Chemnitzia zebra, Gabb.
C. Texana, Roemer.—Cretaceous of Texas.
Tylostoma mutabilis, Gabb.
Anchura monilifera, Gabb.
Cerithium Mexicanum, Gabb.
Turritella seriatim-granulata, Roemer.—Texas.
Angaria (*Delphinula*) *cingulata*, Gabb.
Cinulia rectilabrum, Gabb.
Pholadomya Sonoriensis, Gabb.
Tapes Hilgardi, Shumard.—Cretaceous of Texas.
Cardium (*Granocardium*) *subulosum*, Gabb.
C. (*Protocardium*) *granuliferum*, Gabb.
Cardita? alticosta, Gabb.
Pinna sp. indet.

[1] Geological Survey of California, Palæontology, II, p. 258.

[2] A preliminary notice of the Sonoran fossils was published in vol. III of the Proceedings of the California Academy of Sciences, 1864, p. 153 The fossiliferous rock, as described by M. Rémond, lies about a league and a half east of Arivechi in the Sahuaripa Valley, and consists of clay-slates, 400–500 ft. in thickness, resting upon barren sandstones, and underlying thick strata of compact bluish limestone. "The strata dip to the south-east with an inclination of from thirty to fifty degrees, and form the first range of foot-hills of the Sierra Madre."

Trigonia Mooreana, Gabb.—Cretaceous of Texas.
(*Trigonia crenulata*, Roemer).
Remondia furcata, Gabb.
Gryphea mucronata, Gabb.
Exogyra plicata, Lam.—Cretaceous of Texas.
Ostrea sp. indet.
Pyrina Parryi, Hall.—Cretaceous of Texas.
Cyphosoma Texanum, Roemer.—Cretaceous of Texas.
Turbinolia? Texana, Conrad.—Cretaceous of Texas.

There can be no question, it appears to me, that these fossils represent, as Gabb also supposed, a part of the Upper Cretaceous formation, synchronous with at least some of the deposits described by Roemer from Texas (Senonian or Turonian). Most of the species are beautifully, or, perhaps more properly, artistically, figured in Gabb's report, but in many cases the artistic effort renders determination from them all but impossible. Having had the type-series under my eye among the collections of the Academy of Natural Sciences I venture to subjoin the following notes on species, in anticipation of a more extended report which it is my intention to prepare at a future day.

Ammonites Pedernalis, Von Buch.

I am not sure that the form here described is really Von Buch's species. Gabb calls attention to the flattened dorsum in distinction to the sharp back of the typical *A. Pedernalis*, but remarks that he has observed variation in this respect. But whether the form or not, it certainly represents the group which Von Buch has designated "Cretaceous Ceratitic Ammonites."[1] In Gabb's figure (Pl. 35, fig. 1, 1a) the folds on the surface are much too numerous and regular; not more than one-half the number appear in the single type-specimen, and they are more in the nature of "swellings" than true plications. A portion of the inner whorl that is exposed is entirely destitute of these folds, and shows the ceratitic markings very clearly.

[1] Ueber Ceratiten—Von Buch's Gesammelte Schriften, II, p. 871, Berlin, 1885. The species is referred by Neumayr and Uhlig to the group *Engonoceras* (Ueber Ammonitiden aus den Hilsbildungen Norddeutschlands, Palæontographica, 1881, p. 138), while by Douvillé, who more accurately represents the sutural configuration, it is placed in *Sphenodiscus* (Classification des Cératites de la Craie, Bull. Soc. Géol. de France, 1890, pp. 288–89.)

Gryphæa mucronata.

I see no reason to separate this species from *Gryphæa navia* Conrad (*G. Pitcheri ?* Morton), despite the points of difference indicated by Gabb. Dr. White, in his review of the "Fossil Ostreidæ of North America," has correctly referred it to that species.[1]

Cardita alticosta.

This species is unrecognizably figured. The radiating ribs are in nearly all cases prominently echinated—instead of being smooth—and they are placed much closer to one another than appears in the drawing. As the specific name *alticosta* is preoccupied by a well-known fossil from the Tertiary deposits of the United States (*Cardita alticosta* Conrad+ *C. Blandingi*), I would propose for the Mexican species the name *Cardita Arivechensis.*

Trigonia Mooreana.

Gabb is right in separating Roemer's *Trigonia crenulata* of Texas from the true *Trigonia crenulata* of Europe. The closely placed ribs of the latter, and its deep lunular groove, serve readily to distinguish it from *Trigonia Mooreana.*

Remondia furcata.

This peculiar trigonioid species, for which Gabb created the new genus *Remondia,* is seemingly closely related to *Astarte Bronnii,* of Krauss, from the Cretaceous deposits of South Africa.[2] I know of

[1] 4th Annual Report Director U. S. Geol. Survey, 1884, p. 302. As regards the species or varieties of grypheate oysters occurring in the Cretaceous deposits of the southern United States, and known as *Gryphea Pitcheri, G. dilatata, G. navia, G. Tucumcarrii* and *G. Washitaensis,* I believe they are all referable to a single, or at most, two species—*Gryphea Pitcheri* (Morton) and *G. navia* (Conrad). Whether or not these two should be considered distinct, will depend upon the view of species which each paleontologist holds. They are certainly very closely inter-related, and I believe that Dr. White is right in recognizing only *G. Pitcheri* and *G. Pitcheri* var. *navia* (*Loc. cit.* pp. 302–3. *Gryphea Pitcheri* was first described from the Cretaceous deposits of Arkansas, and not from New Jersey, as is sometimes assumed). Roemer's figures (Plate IX, figs. 1a, b, c—Kreidebildungen von Texas, 1852) represent the variety *navia,* as do likewise figs. 5 and 6 of Marcou's Plate IV (Geology of North America, 1858). *Gryphea Washitaensis* of Hill (Annotated Check List Cretac. Invert. Fossils Texas, Bulletin 4, Geol. Survey of Texas, p. 4, 1889), specimens of which Professor Hill has kindly sent to me, is true *G. Pitcheri,* corresponding almost absolutely with the type specimen of that species (Morton's) which is contained in the collections of the Academy of Natural Sciences.

[2] Nova Acta Acad. Cæsar. Leop. Carol., XXII, p. 449, pl. 48, figs. 1, a, b c, d, e.

no other form that approaches it. Zittel refers both species to the genus *Remondia*.[1]

Chemnitzia zebra.

This species is poorly drawn. The spire broadens out considerably more than is represented in the figure (pl. 35, fig. 5), and the whorls are almost flat-sided.

Anchura monilifera.

The figure-measure (pl. 35, fig. 7) is considerably larger than the specimen actually figured, and it exceeds by about one-sixth the largest specimen in the collection.

Euspira tabulata.

Gabb states that this species "looks much more like a Jurassic than like a Cretaceous species" (p. 260). I cannot concur in this opinion. The Academy collections contain specimens of *Natica subbulbiformis* D'Orb., from the Cretaceous deposits (Turonian) of Uchaux, France, which are barely distinguishable from the Mexican form.

Natica Pedernalis, as it is represented on Plate 35, fig. 3, does not exist. The figure is compounded from two fossils, which have little in common with one another, and seemingly represent two distinct genera. The specimen which gives the outline to the drawing is very imperfect and shows no trace of an umbilicus. I doubt much if it is even a member of the *Naticidæ*. The second form is a true *Natica*, which may or may not be Roemer's *N. Pedernalis*, the type cast of which does not permit of the identification of the species. The Mexican specimen, although somewhat distorted, is perfectly preserved, and I cannot understand how Gabb could have confounded it with the form which he erroneously describes and figures as *Natica Pedernalis*.

Neither the material published by Gabb, nor the somewhat more extended note on the formation which is furnished by Rémond,[2] is sufficient to allow us to state positively whether the deposits in question are absolutely synchronous with those of Jalapa and Tehuacan or not. Probably they represent a somewhat lower stage of the Cretaceous and are the quivalent of a portion of the Cenomanian. By Dr. White the beds are correlated with the Comanche

[1] Handbuch der Palæontologie, II, p. 58.

[2] Notice of Geological Explorations in Northern Mexico—Proc. California Acad. Nat. Sci. III, pp. 5 and 11, 1866.

or lower series of the Texan Cretaceous,[1] but the position of these beds in the true geological scale is not stated. Roemer referred all the Cretaceous deposits of the State of Texas to the Turonian and Senonian of D'Orbigny, but Prof. Hill, as the result of more recent surveys, places the Comanche series in the Lower Cretaceous formation.[2] This determination is, it appears to me, erroneous, and is not borne out by the lists of fossils which are given by Prof. Hill. The deposits may strictly be the Lower Cretaceous of America, but they are not the correspondents of what is recognized as the Lower Cretaceous of geologists generally, inasmuch as they represent a horizon at least as high up in the series as the Cenomanian (not Neocomian, as stated by Hill). It is only necessary to name a few of the species indicated by Prof. Hill as occurring in the formation to be convinced of the true (comparatively high) position of the horizon: *Exogyra Matheroniana, Ostrea carinata, Pecten æquicostatus, Pecten quadricostatus* (?), *Protocardia Hillanum*, etc., all well-known European forms, and mostly distinctive of the Cenomanian horizon. In addition to these forms *Janira Fleuriausiana*, of D'Orbigny, also a Cenomanian form, is enumerated in one of the lists.[3] Prof. Hill refers to a species of *Crioceras* (*Ancyloceras*) as indicating the Neocomian horizon, but the form in question has been identified by Prof. Hyatt with *Lituites Bickmoreanus*, from the Niagara (Silurian) limestone of Indiana;[4] nor is the generalization correct that the presence of Rudistes, Nerinæas, Pleurotomarias, and Globiconchas "while not decisive, is corroborative of the low position of the Comanche series."[5] If the word "high" were substituted for "low" the generalization would have been more nearly correct. It is stated that "it was chiefly upon the evidence of the *Exogyra Texana* and the *Ostrea carinata* that Roemer made this Comanche series belong to the Upper Chalk of Europe." This is hardly the fact. Roemer rightly emphasizes the presence in the formation of *Cardium Hillanum* and *Pecten quadricostatus*—European Upper Cretaceous species—and of the following analogues of the Upper Cretaceous species: *Actæonella dolium* (representing *A. lævis*),

[1] Proc. Acad. Nat. Sciences, Phila. 1887, p. 43.

[2] Check List Cret. Inv. Foss, Texas, 1889; Am. Journ. Science, 1887, pp. 303–307.

[3] Am. Journ. Science, 1887, part 2, p. 303.

[4] Hill, Check List, p. 21.

[5] Am. Journ. Science, 1887, part. 2, p. 307.

Arcopagia Texana (rep. *A. numismalis*), *Cardium Sancti Sabæ* (rep. *C. caudatum*), *Avicula convexo-plana* (rep. *A. anomala*), *Exogyra Texana* (rep. *E. Matheroniana*), and *Cyphosoma Texanum* (rep. *C. tiara*). *Toxaster Texanus* appeared to this observer to be the only fossil indicative of a low horizon.[1]

The cumulative evidence that we have, thus tends to prove that the Comanche beds of Texas occupy a horizon not lower than the Cenomanian; in other words, they are a part correspondent to what some geologists recognize as the Middle Cretaceous, and what others, who admit but two divisions in the formation, class as Upper Cretaceous. They are distinctly *not* Lower Cretaceous (or Neocomian) and this lower member of the series has still to be found in the United States east of the Rocky Mountains.[2] The opposing evidence of the single Echinoid, *Toxaster*, counts for little in this connection.[3]

M. Virlet d'Aoust in a paper "Coup d'œil sur la Topographie et la Géologie du Mexique et de l'Amérique Centrale," mentions the occurrence of a Hippuritic limestone, containing numerous Echinoids, near Tula, State of Hidalgo, about 40 miles north of the city of Mexico.[4] Without doubt this is a portion of the limestone, rich

[1] Kreidebildungen von Texas, p. 18.

[2] Prof. Hill appears to have been, to a certain extent, misled in his correlation of the Texas and Arkansas Cretaceous deposits through an unfortunate error which is contained in Prof Whitfield's Report on the "Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey" (Monogr. U. S. Geol. Survey, 1885). It is there stated that *Exogyra costata* occurs only in the "Lower Marl Beds" of the State (pp. XVIII, 41), and this assertion is accepted by Hill (A. J. Science, 1889, part 2, p. 472—"Relations of the Uppermost

[3] Cotteau has recently described or recorded a number of Echinoids, from various parts of Mexico, which he considers to be indicative of the Lower Cretaceous horizon (Bulletin Soc. Géol. de France, 1890, pp. 292–99—Echinides Crétacés du Mexique). These are: *Pseudocidaris Saussurei*, from San-Juan Raya, in the State of Puebla; *Salenia prestensis*, from Guadalupe, Chihuahua; *Enallaster Mexicanus*, from Guadalupe (Chihuahua) and Colima (Colima); *Diplopodia* (*Pseudodiadema*) *Malbosi*, from Arivechi, Sonora and *Holectypus Castilloi*, from Jalpa, Jalisco. The last named species is considered to represent either the Lower or the Middle Cretaceous. *Pseudocidaris Saussurei* occurs also in the deposits of Tehuacan, and is the form which Nyst and Galeotti erroneously referred to *Cidaris glandiferus* of Goldfuss; the species is thus manifestly Upper Cretaceous. Again, the so-called *Diplopodia Malbosi*, which is identified from two imperfect specimens, both of which differ in certain characters from typical representatives of that species, is admitted to be "assurément voisine de *Diplopodia variolaris*" (Cotteau, *loc. cit.*, p. 294), which is also a distinctively Upper Cretaceous species.

[4] Bull. Soc. Géol. de France, 1866, p. 23.

in Hippuritic remains, which crops out at Apasco, and which has been referred to by Ramirez in his "Memoria para la Carta Geologica del Distrito de Zumpango."[1] I have seen the fossils from this region, and am satisfied that they are largely identical with those found in the Hippuritic limestones on the south side of the Mexican plateau, in the mountains of Tehuacan and of Yautepec. Virlet d'Aoust mentions the occurrence of broadly-distributed beds containing *Ananchytes sulcata*, but it has not been my good fortune to meet with this very characteristic fossil of the Chalk (Senonian), nor have I seen it in any of the collections of Mexican fossils.

Without doubt the limestone of Tula and Apasco is identical with that which Bárcena has recorded as occurring in Querétaro, and in the districts of Yolotepec, Zimapan and Jacala, in the State of Hidalgo, where the rock contains impressions of Hippurites, Radiolites and Nerinæas.[2] That this is a part of the true typical Upper Cretaceous formation, the character of the fossil remains, it appears to me, abundantly proves. Bárcena, while recognizing the Cretaceous age of the formation, mentions the occurrence in it of a supposed Jurassic fossil, *Nerinœa hieroglyphica*. The same fossil was also found by Bárcena, associated with *Hippurites*, *Radiolites* (referred to as *Crania*), etc., in the rock of the Cave of Cacahuamilpa, in the northern part of the State of Guerero, and the distinguished Mexican geologist was originally led to conclude from this occurrence that

Cretaceous Beds of the Eastern and Southern United States;" "The Neozoic Geology of Southwestern Arkansas," Report Geol. Surv. Arkansas, 1888, p, 106). The statement is, however, erroneous: *Exogyra costata* is an abundant fossil of the red sands which underlie or form the base of the Middle Marl Bed (as may be seen in the section at Mullica Hill), where it is associated with *Gryphea vesicularis*, *Belemnitella mucronata*, etc. Its position, in fact, is very near to the top of the Cretaceous series of the State.

It is much to be regretted that American geologists so persistently use the almost meaningless terms "upper" and "lower" as applied to formations occurring in special localities, without determining or stating the relations of such terms in a general geological classification. This indiscriminate use of broad subdivisions cannot but lead to confusion. How often we hear mention of Lower, Middle and Upper Cretaceous deposits of New Jersey, when in reality beds referable only to the Senonian and Danian (possibly also the Turonian)—consequently, equivalents only of the higher Cretaceous of the continent of Europe and of England—are intended; indeed, a Jurassic deposit has even cropped up in the same State,

[1] Anales del Ministerio de Fomento, Mexico.

[2] Anales del Ministerio de Fomento, Mexico, 1, 1877, p. 349.

the formation in question represented a transition bed between the Jurassic and Cretaceous systems.[1] I am not acquainted with the species to which the form figured[2] by Bárcena is referred, nor am I able to determine its special Jurassic features. On the other hand, I have identified the same species, associated with an abundance of Hippurites and with *Nerinœa Castilli* (Bárcena), in the limestone of the Cerro de Escamela, near the town of Orizaba, whose position in the Upper Cretaceous series (Senonian) is well established. The fragment from the same region which Bárcena doubtfully refers to *Nerinœa Goodhalli* (Jurassic) is much too imperfect for recognition.

Ramirez has identified, as he believes, the limestone of Apasco in the Sierra Mojada of Coahuila, which would carry the formation close on to the Texan frontier. The determination is based largely upon the recognition in both localities of an identical species of Hippurite, which the author figures.[3] The form certainly appears identical with a species which I have myself collected in the southern mountains, and which is also reported from Tancanhuitz, in the State of San Luis Potosí. It seems to me possible, however, that a portion of the Sierra Mojada limestone may represent a somewhat lower horizon, the Cenomanian (=the formation of Arivechi, in Sonora), but the data on this point are still obscure. Ramirez enumerates and

since a local bed, containing some fossil remains less Cretaceous in aspect than those found in the upper beds, has been found to underlie the so-called Lower Cretaceous. Dr. White, in his valuable paper on the "Lower Cretaceous of the Southwest" (Am. Journ. Science, 1889, 2nd part, p. 440), well recognizes that the Lower Cretaceous of that section of the United States is not the equivalent of the Lower Cretaceous of Europe, and it is therefore the more to be regretted that he makes use of a classification which cannot be of general application. The confusion arising from such loose classification is immediately shown in the conclusions that are deduced from it. Thus, being Lower Cretaceous (in the American sense), Dr. White seeks for the equivalents of the Comanche series in the Lower Cretaceous of Europe, and it is perhaps not surprising that "we cannot say with confidence that the Comanche series really represents any one of the divisions of the European Cretaceous from the Gault to the Lower Neocomian inclusive" (*loc. cit.*, p. 442). Assuredly not, since the deposits in question lie above the European Lower Cretaceous, and are, as I have shown, not older than the Cenomanian.

[1] Viaje a la Caverna de Cacahuamilpa, p. 17, Mexico, 1874.

[2] Datos para el Estudio de las Rocas Mesozoicas de México, p. 12, 1875; Materiales para la Formacion de una Obra de Paleontologia Mexicana, Anales del Museo Nacional de México, 1877, p. 201.

[3] Exploracion en la Sierra Mojada—Anales del Ministerio de Fomento, 1880, pl. 1, fig. 1.

figures a number of fossils, some of which at least, seem to more nearly represent the Middle Cretaceous than the Upper Cretaceous system. Such is the Ammonite referred to *Ammonites inflatus*, which it really appears to be. The second form of Ammonite, which is identified with *Ammonites planicostatus*, is hardly that species, if the drawing is at all to be relied upon; the broad back and crowded costæ distinguish it from the well-known European species. It seems to be more nearly a member of the group of *A. Mantelli*, if indeed, it is not that species. The large gasteropod, which is identified with *Pterodonta inflata* (Cenomanian), is scarcely in a condition to be determined; it may, or may not, be that species, or it may be a true *Tylostoma*. Ramirez also figures (and comments upon its occurrence here) a *Posidonomya*, but the imperfect drawing does not permit the form to be recognized, or to be distinguished from a young Inoceramus.

I am not aware that the great limestone formation of South-Central Mexico has been identified in the northern part of the Republic east of the Sierra Mojada region, except along the immediate borders of the Rio Grande. It is more than likely that it outcrops in the State of Nuevo Leon, as Dr. White has evidence for believing,[1] but I know of no positive statement to that effect. The supposed Cretaceous which Wislizenus describes as being found near Mier, on the Alamo River, about four miles above its discharge into the Rio Grande[2] (State of Tamaulipas), is Tertiary, and with little doubt either Miocene or Oligocene. The large oyster occurring there is manifestly the species which is referred to by Penrose as occurring on the Rio Grande, near Roma, Texas, and is doubtfully identified with Conrad's *Ostrea Georgiana*.[3]

The oyster is, however, not *Ostrea Georgiana*, but a much more ponderous form, and one which is barely to be distinguished from *Ostrea Gingensis*, of Schlotheim, a giant species of the Miocene deposits of continental Europe; the specimen in my possession measures a foot in length and fully six inches in width. Dr. Penrose is, I believe, justified in (doubtfully) referring the beds in which it occurs to the base of the Grand Gulf Series; the horizon represented is surely above the Eocene.

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[1] Am. Journ. Science, 1889, part 2, p. 441.

[2] Memoir of a Tour to Northern Mexico, U. S. Senate Publications, 1848, p. 138.

[3] First Annual Report, Geol. Surv. Texas, 1889, pp. 46, 50, 56.

Dr. White mentions[1] the occurrence of heavy deposits of hard blue limestone of the Comanche series in the Sierra San Carlos, in the State of Chihuahua, 75 miles southeastward of Presidio del Norte; the beds are here said to have a thickness of not less than 4000 feet, and are thrown into a nearly vertical position, with the so-called "Upper" Cretaceous beds lying conformably on their eastern face. It is probably from the lower portion of this series that Wislizenus obtained (through presentation) the *Pecten quinque-costatus* (Cenomanian), which was reported to have come from a locality, near Corralitas, "about 250 miles northwest of Chihuahua."[2]

The numerous localities that have here been cited for the occurrence of Cretaceous fossils on and beyond the Mexican plateau indicate the broad range over which the deposits of the period were laid down; there can be little or no question that all the outcrops that have been observed are either now united continuously with one another, or had been so united during the time of their formation and uplift. The great volcanic outpourings which followed the catastrophic uplift have largely obscured the giant masses of the formations, whose full forms are still so beautifully displayed along the eastern and southern edges of the plateau, but we find the connections in the scattered islands or oases of rock which have from time to time been noted in the interior states.

The preceding references cover outcrops in the States of Sonora, Chihuahua, Coahuila, Nuevo Leon (?), San Luis Potosí, Hidalgo, Vera Cruz, Puebla, Mexico, Morelos and Guerero, but the formation has also been identified in Jalisco, Colima,[3] Zacatecas (at Noria de Angeles, Fresnillo, Veta Grande, etc., along the spurs or extensions of the Asientos Mountains of Aguascalientes), Aguascalientes (district of the Cerro de Temascal, the Asientos Mountains),[4] Querétaro (district of the "Doctor"), and Michoacan (district of Coalcoman).[5] Over all this area there is a remarkable similarity in the

[1] Am. Journ. Science, 1889, part 2, p. 444.

[2] Op. cit., p. 138.

[3] On the authority of Antonio del Castillo, as stated by Bárcena—Datos para el Estudio de las Rocas Mesozoicas de México, p. 34.

[4] Bárcena, Noticia Geologica del Estado de Aguascalientes, 1876, p. 2.

[5] Urquiza, Exploracion del Distrito de Coalcoman, Estado de Michoacan—Anales del Ministerio de Fomento, VII, 1882. The fossils found in this region have been referred by Urquiza to *Hippurites bioculata*, *H. calamitiformis*, *H. Mexicana*, *Radiolites turbinatus*, *R. foliaceus ? Astarte* sp. indet., *Pecten* sp. indet.,

general lithological features of the formation—which is largely composed of massive cream, gray and blue (partially bituminous) limestones and marbles—and in the fossils which they contain. The rocks over the greater part of their extent pitch at steep angles, but in some districts they dip regularly and evenly over long distances; in others they are badly folded and dislocated, and rapidly alternate in inversions and fractures. This condition is especially well marked on the eastern face of the plateau, and can be seen at many points along the line of the Mexican Railway between the Boca del Monte and Nogales. In the deep gorge of the Infierno, below Maltrata, the effects of crushing are exhibited on a wonderful scale. The predominant strike of the formation seems to be N. W.—S. E., with dips both to the eastward and to the westward, and it is carried along this line, or in a direction more nearly north-and-south, in the long declining ridges (as in the mountains of Tehuacan and Yautepec) which continue the formation of the plateau into the lowland beyond the southern scarp. In the first range of elevations facing the Gulf, as I observed in the Chiquihuite Mountains near Atoyac, the strike is directed N. E.—S. W. (with a steep dip to the southeast), the limestone ridge trending off in the direction of the foothills east of Jalapa; possibly the special forces which built up the giant trio of volcanoes situated on the eastern edge of the plateau—Orizaba, the Sierra Negra and the Cofre de Perote—were the determining factors in producing this change in position. In the Atoyac or Chiquihuite range the limestones are of a cream color, heavily bedded, and compact in texture, much resembling in places lithographic stone.

For a long time I searched in vain for fossil remains in these rocks, but eventually discovered, both above and below the town of Atoyac, a number of beds of limited extent which were densely charged with organic fragments. Their condition of preservation was in most cases too unsatisfactory to permit of either specific or generic identification, but I determined the outlines of several Hippuritidæ,

Gryphea sp. indet., *Nerinæa Castilli*, *N. hieroglyphica*, *Pterodonta* sp. indet., and among corals, *Trochoseris sinuosa* and *Thamnastræa pedunculata*. From personal knowledge I can say but little regarding these determinations. The identification of the *Hippuritidæ* and the *Nerinæas* is probably in the main correct. I have myself observed the former in the rock of Coalcoman, and Bárcena mentions *Radiolites Mendozæ* (=*R. foliaceus?*), in association with *Hippurites* and *Nerinæa Castilli*, as occuring in the State (Anales del Museo Nacional, 1877). The determinations of the species of coral are, with little doubt, erroneous.

as well as of their finely striated cortical surfaces. The latter in section much resemble some of the giant Foraminifera, while the cups, where they partially protrude from the rock, strikingly recall the rugose corals. I have little doubt that it is from these resemblances that some of the Mexican (Cretaceous) limestones have from time to time been referred to the Paleozoic period, and it was sometime before I could myself determine the precise nature of the fossils which it was my good fortune to discover. No mention of their occurrence in these rocks is, so far as I am aware, made by any earlier investigator. The discovery is particularly interesting since it helps to delimit the eastern boundary of the Cretaceous deposits at a point far removed from the actual crest of the plateau. To what extent these same rocks extend Gulf-ward beneath the capping of lava, boulders and volcanic sand which fills in the basal plain east of the first true range of mountains, I could not ascertain. But it is certain that the limestone is largely developed in these eastern lowlands, and it is more than probable that the outcrops which appear in and about the line of the Vera Cruz-Jalapa railroad, such as I had occasion to observe at Plan del Rio, at an elevation of about 1000 feet above the sea, are a continuation of the Atoyac rock, just as the fossiliferous rocks about Jalapa and Coatepec are a continuation of the rocks of Orizaba. I failed, however, to find any trace of fossils in the rock of Plan del Rio, nor could I obtain any positive information from the natives that any such fossils had been found; but the rock is lithologically very similar to that of Atoyac, which is also largely non-fossiliferous, and it lies directly in the line of strike of the Chiquihuite mountains—i. e. in a line parallel with the eastern crest of this portion of the plateau.

The Cordoba Mountains, which succeed the Chiquihuite range westward, are without doubt a part of the same system of elevations which begin with the latter as their lowest crest and culminate in the chain, rising to a total elevation of some 8500 feet, which passes southward from the plateau in the region of Esperanza. Being projections on the plateau itself, this chain presents the appearance of insignificant hills, but the crests can be followed fifty or more miles southward, along the declining valley of the Rio Salado, when the full height of the mountains appears in thousands of feet of elevation.

The typical fossiliferous strata of the Upper Cretaceous period are beautifully exhibited in the steep beds of the Cerro de Escamela, just outside of the town of Orizaba. Fossils are here very abund-

ant, and they can be readily identified on the polished surfaces of the marbles which are worked in the village of Nogales. I determined here various forms of Hippuritidæ—*Hippurites, Radiolites, Ichthyosarcolithes*—*Nerinæa Castilli*, the species of *Nerinæa* referred to by Bárcena as *N. hieroglyphica* and *N. Goodhalli*, a species of *Murex*, a large *Actæonella* (?) or possibly *Tylostoma*, and the oyster which Bárcena has identified with *Ostrea virgula*. The Escamela Mountain, as determined by Guillermo G. y Puga, rises 1417 feet above the valley, or to absolute height of some 5800 feet. To the opposite side of the town of Orizaba the Borrego presents a steep face, some 800 feet in height, of heavily bedded blue limestones whose general dip is to the southwest. I found no fossils in this rock, and I suspect that it belongs to a somewhat different horizon from that of the gray marbles of the Cerro de Escamela, but I could not absolutely satisfy myself as to its true relations.

In the valleys leading out from Orizaba there are a vast series of river deposits, which appear here and there exposed in massive stratified beds of shingle, sand, and trap boulders. The section along the Metlac, whose one face is bounded by limestone, well exhibits this feature. But I could nowhere find any evidence of interbedding with the limestone such as Guillermo G. y Puga represents in his geological section along the line of the Mexican Railway from Orizaba to Vera Cruz.[1] These river deposits are all comparatively recent, and can be traced almost completely across the coast-land to the sea.

Between Orizaba and the eastern crest of the plateau the limestones, rising higher and higher, are exposed in almost continuous section. In the deep gorge of the Infierno, below Maltrata, the shattered and contorted beds form a wonderful exhibit, and bear witness to the tremendous strains that were impressed upon the rock-masses at the time of their uplifting. It seems to me probable that the mountains about here have suffered secondary dislocation, having been warped and twisted from a primal position through successive volcanic squeezes and discharges. Along the northern face of the gorge heavy beds of lava, representing probably an early discharge from the Sierra Negra, rest directly upon the limestone, which appears, however, to have suffered but little alteration through contact with the igneous mass. Above Maltrata the rock-

[1] La Naturaleza, 1888, pp. 49–53. With little doubt the section was inadvertently drawn in its present form to represent interbedding.

fractures and dislocations follow rapidly on one another, and in short intervals the beds assume all positions and reversions. No more magnificent display of mountain architecture can be conceived than that which is presented in the steep upper face of the plateau scarp. In some places, as at Alta Luz, the strata become "flaggy," and appear in thin shales verging on to slates. Possibly it is some of this rock, having a clearly ancient look, which geologists have from time to time considered as being Palæozoic. Dollfuss[1] mentions the occurrence of Palæozoic strata near the Boca del Monte, but I failed to find any such outcrop; and I am certain that the series of Palæozoic strata, from the Carboniferous to the Silurian, which Packard mentions[2] as outcropping between the eastern crest of the great central plateau and the basal plain does not exist.

For some distance after the summit of the plateau is reached, up to and beyond the town of San Andres, the limestone appears in low ridges trending southward, which ridges are but the backbones of the main chain rising through the flat surface of the plateau. We traced these seemingly low ridges southward to Tehuacan and beyond, following in the line of the rapidly declining valley of the Salado. With our descent from the plateau the hills, becoming more and more exposed to their bases, rose majestically above us, and were seen to constitute a true axial system of mountains, the inner folds, manifestly, of the system which builds up the eastern face of the plateau. Black cinder cones appear at intervals planted on the white limestone. In the region immediately about Tehuacan, the height of the ridges locally known as the Sierra de San Antonio Tlascala and Sierra San Felipe Maderas cannot be less in places than 8000–9000 feet (absolute elevation). The dominant dip of the beds, which outcrop in sharp lines on the eastern faces of the hillsides, is westward, with varying angles.

In the trough of the long sloping valley which leads southward from the plateau vast deposits of detrital material have accumulated; masses of shingle and boulders, representing largely the debris from the table-land, are exposed in all the stream-cuts, and build up river-terraces of broad extent and distribution. Secondary lime deposits, known as *tepetate*, have resulted from the re-deposition of

[1] Observations Géologiques, Arch. Comm. Scientifique du Mexique; Felix und Lenk, Beiträge zur Geologie und Paläontologie der Republik Mexico, p. 11, 1890.

[2] American Naturalist, XX, p. 122.

of the higher volcanic ash-sands, or through simple precipitation from waters highly charged with lime-carbonate. Much of this deposit is strikingly firm and compact, and in parts so completely interwoven with the basal limestone of the region as to be only with difficulty distinguished from it. Bones of one or more forms of extinct elephant are found imbedded in the tepetate.

From any of the eminences about Tehuacan the valley can be traced southeastward very nearly to the limits of vision, with the bounding ridges following in the same direction into the State of Oaxaca (where they are met by a more or less transverse system of elevations). The fact that these ridges pass for such long distances beyond the true edge of the plateau, and retain throughout a general parallelism of structure, is to me sufficient evidence that the plateau is not the result of uplift along an east-and-west line of faulting, such as has been assumed by Felix and Lenk, and which is made by these authors to conform with the (assumed) east-and-west fissure upon which the principal volcanic vents—Orizaba, Popocatepetl, Nevado de Toluca, Jorullo—are supposed to stand. The plateau, in this part at least, represents compressional uplift, in which an east-and-west thrust has produced a series of folds running in a direction more or less at right-angles to this line. The inequalities or saddles of folding have been largely filled in through volcanic and fissure discharges, which have thus mainly been instrumental in shaping the existing physiognomy of the plateau. Parallel chains of hills or mountains, similar to those of the region about Tehuacan, also pass southward from the plateau in the State of Morelos, near Cuautla and Yautepec, and between Yautepec and Cuernavaca, but these will be considered later on.

About ten miles to the southward of Tehuacan, following in the direction of San Antonio and Zapotitlan, are the hills upon which are situated many of the quarries of the famous Mexican onyx ("Esperanza marble"). They lie at an elevation of between 6000 and 7000 feet, where the chain is deflected slightly to the northwest, with a dip of the strata varying from west to southwest. This so-called onyx occurs in light and heavy beds, sometimes several feet in thickness, and is manifestly an infiltration product of a stalagmitic nature. It is, in fact, a floor or crust stalagmite, interbedded with the distinctive Cretaceous limestones. I found numerous fossils of the Hippuritic period in beds both underlying and overlying the onyx, so that there can be no question as to the posi-

tion of that rock; but when it was formed—how soon or how long after the close of the Cretaceous epoch—there seems to be no data for determining. And for aught we know to the contrary, the onyx may be forming to-day.[1]

Westward of the region that has just been described the limestone ridges are continued through much of the State of Puebla, both on and off the plateau; while many of the more characteristic fossils that occur elsewhere have not yet been recognized in these deposits, their position and association leave no doubt that they are a belonging, in part at least, of the same general Cretaceous formation which occupies so much of the Republic.[2] Some of the most extensive deposits of Mexican onyx, here known as "Puebla" marble, are worked in the region about (southwest of) Tecali, a few leagues to the south of the city of Puebla.[3]

In the State of Morelos, most marked in the region of Cuautla and Yautepec, limestone ranges similar to those of Tehuacan trend southward from the plateau scarp; more properly, perhaps, they might be described as abutting against the southeastern face of the plateau, whose giant volcanic masses are reared up in imposing grandeur in bastion-like towers and mural serrations, thousands of feet in elevation. The emergence of the limestone from the abrupt wall of the plateau is here clearly marked. Between Cuautla and Yautepec the parallel ridges of limestone are but feebly devel-

[1] Many workers of the onyx believe the rock to be a united breccia, or a compound of large angular fragments which cross one another in all directions. This misconception arises from the peculiar interblending of the laminal lines in geodic sections, appearing as though distinct blocks of rock had been brought in opposition. The broken appearance is in reality only the result of involution, by which different sections of the same series of laminæ are brought into a variety of antagonistic positions.

[2] Bárcena describes *Ammonites James-Danae* from Acaxochitlan, Ferreria de la Trinidad, and Abra de Huilacapixtla (Anales del Museo Nacional, I, p. 286 1877). The author justly calls attention, as had already been done by Mr. Meek, to the Jurassic aspect of this Ammonite (*Arietes ?*), which much recalls the type of *A. Bucklandi*. Whether the presence of this form alone can be considered sufficient evidence for recognizing in the region of its occurrence a Jurassic formation I am not prepared to say. It may be a Jurassic type which has lingered well on into the Cretaceous period; or, the discovery of additional fossils may clearly establish the existence of true Jurassic deposits. There is nothing in the stratigraphy of the rocks of the region which, as far as I can see, is opposed to the pos-

[3] Bárcena—Las Rocas de Tecali —La Naturaleza, III, 1876, pp. 7–9; Proc. Acad. Nat. Sci. Phila., 1876, p. 166.

oped, rising from 150 to 200 or 300 feet above the general level of the country; yet, if their elevation above the level of the sea is considered, they are mountains of noble proportions, rising to nearly 5,000 feet West of Yautepec, however, they gradually increase in height, and in what is locally known as the Sierra Blanca—the long divide which separates the region of Yautepec from that of Cuernavaca—they attain an absolute elevation of probably not less than 6,500 or 7,000 feet, thus reaching to within a short distance of the actual level of the plateau. Mr. Baker and I traversed the eastern slope of the divide to an elevation a little exceeding 6,000 feet. The general features of the region, both in their geological and botanical aspects, are very similar to those of the mountains of Tehuacan and Zapotitlan. Heavy beds of white or gray limestone crop out on the hillsides and give to them that distinctive light color which so eminently serves to distinguish the sedimentary deposits from the dark, in some places almost black, volcanic masses ("Sierra Negra") with which they are associated. We found the dip of the beds to be uniformly east or southeast, with a declination ranging to nearly 40 degrees. A short distance to the westward of Yautepec, a volcanic cone, whose lava-stream reaches the town, rises through the limestone ridge, but I could not detect that the dip of the beds was materially affected by its presence; both east and west of it the beds dipped eastward, and at almost identical angles. A slight

sibility or probability of Jurassic masses being here and there protruded through the Cretaceous limestones, and indeed, such protrusions and intercalations may be much more numerous than the general similarity of the rock-masses would lead one to suppose. Nikitin has also quite recently described (Einiges über den Jura in Mexico und Centralasien—Neues Jahrbuch für Mineralogie, 1890, p. 273) what are assumed to be Jurassic fossils (*Aucella*, closely related to *A. Pallasi*, etc.) from the region about San Luis Potosí, and he identifies the formation containing the fossils as the equivalent of the Russian "Aucella beds." It is, however, not at all unlikely that a number of Jurassic forms have actually survived in the Mexican region into the Cretaceous period, and possibly the *Aucella* (which in Europe survives into the Tithonian étage=passage beds between the Jurassic and the Cretaceous and into the Lower Cretaceous itself) is one of these. Bárcena assumed that the *Nerinæa* which he referred to *N. hieroglyphica* was a Jurassic form, and he also cites the occurrence of *Ostrea* (*Gryphea*) *virgula* in the limestone of Apasco (Datos pare el Estudio de las Rocas Mesozoicas, p. 18); but this limestone, as has already been seen, is a part of the true Hippuritic series, and a member, consequently, of the Cretaceous system. I have also found the same species of oyster, whether true *Ostrea virgula* or not, in the Escamela rock of Orizaba, where it is very clearly associated with the large *Nerinæa*, *N. Castilli*, and with various *Hippuritidæ*; its position there is thus firmly fixed.

variation in the direction was possibly due to intrusion-warping. For some distance around the volcano, however, the limestone beds were shattered into cubical blocks; how far this condition may have been induced through volcanic pressure, I cannot say, but it seems probable that the breakage is not a simple form of jointing. Some of the loose blocks of limestone show distinct traces of scorching and semi-fusion, and are manifestly products of eruption; they are in part crystalline, breaking along well-defined cleavage planes.

We found numerous fossils both in the ejected boulders and, *in situ*, in the stratified layers; unfortunately, their condition of preservation was such as not to permit of specific recognition in most cases, but there was no difficulty in determining the outlines of various Hippuritidæ, and of seemingly the same forms which we had already observed in the limestones and marbles of Orizaba. The same fossiliferous limestone outcrops at various places in the town of Yautepec and forms the Cerro de Calvaria just outside (east) of it. Beautiful exposures are seen along the small stream which, in the center of the town, forms the parting between the limestones and the lava stream which enters from the west; a strong easterly dip is here well shown. There is no doubt in my mind that the limestones of this region, with a pronounced easterly dip, are part of the same series which, further to the east, in the region about Tehuacan, dip in the opposite direction. They represent one section of a chain of folds which passes continuously from the eastern face of the plateau far into its interior, or even completely through it, likewise traversing it from north to south. How many inversions or compressions are involved in this gigantic mountain uplift, research has not yet made clear.

From the summit of the Calvaria hill the eye can readily trace the backbones of the various ridges as they trend southward, until they are lost from view. At their further end these ridges probably inosculate with the series of heights whose trend is directed more or less nearly at right angles to them and whose age belongs to a much more ancient period of geological time.

Paleontology.

With few exceptions, all the fossils that have heretofore been described from the Cretaceous deposits of Mexico are enumerated in the preceding pages. I append herewith a list of a few of the species, with their recognized distribution, which will serve more clearly to

indicate the identity of the formation which covers, or at one time covered, the greater part of the Republic:

Hippurites Mexicana.—States of Mexico, Querétaro, Hidalgo, San Luis Potosí, Coahuila, Vera Cruz, Puebla, Guerero, Morelos.

Hippurites calamitiformis.—Mexico, Querétaro, Vera Cruz, Puebla, Morelos, Michoacan.

Radiolites Mendozæ.—Querétaro, San Luis Potosí, Vera Cruz, Guerero, Michoacan.

Nerinæa Castilli.—Querétaro, Hidalgo, Vera Cruz, Morelos, Michoacan.

Nerinæa Barcenæ (N. hieroglyphica, of Bárcena).—Vera Cruz, Guerero, Michoacan.

Enallaster Mexicanus.—Chihuahua, Colima.

I have little doubt that some of the species above enumerated are found in States other than those mentioned, but the distribution as given sufficiently illustrates the broad range of the species.

Plates XII–XIV illustrate the forms which I myself found in the limestones and marbles of the Cerro de Escamela, near the town of Orizaba. Some of these are clearly identical with the species which Bárcena first described in his "Datos para el Estudio de las Rocas Mesozoicas," but I have thought well to figure them, together with the other unnamed and less recognizable forms, so that they might more readily serve the wants of the paleontological student.

Nerinæa Castilli. (Pl. XII, fig. 1).

The fragment of this species, as shown on a polished surface of marble, measures three and a half inches in length; what the total length of the shell may have been I am unable to say, but it doubtless considerably exceeded half a foot. The species, which Bárcena has minutely described, seems to be well defined from any of its European congeners.

Nerinæa Barcenæ. (Plate XIII, figs. 3 and 4).

This is the form which Bárcena doubtfully identifies with *N. hieroglyphica*, supposed to represent the European Jurassic formation. I have in vain searched for a recognized species of that name, nor have I been able to find a species, either Jurassic or Cretaceous, which agrees in its columellar features with the Mexican fossil. With the strong probability that the identification with a Jurassic form is erroneous, I have thought it best to rename the species, and in doing so take pleasure in recalling the name of the distinguished Mexican geologist, Mariano Bárcena.

Nerinæa sp.? (Pl. XIII, fig. 6).

The form here represented is likely to be a deeper section of the last-named, or it may be the form which Bárcena doubtfully

identifies as *Nerinæa Goodhalli.* The absence of the columellar characteristics prevents positive determination.

Murex *sp. indet.* (Plate XIII, fig. 2).

The drawing is from a tracing made on a polished marble which shows the contour of the species perfectly, but unfortunately fails to furnish the specific characters. I obtained a perfect specimen of the same species in the Escamela quarry, but it was lost before I had an opportunity to fully examine it.

Tylostoma? (Plate XIII, fig. 1.)

Two section-specimens of this large gasteropod were found in the rocks of the Escamela quarry, from one of which the figure was carefully traced. The unequal balancing of the whorls and the somewhat irregular flow of the columellar surface would seem to indicate that the specimen had undergone some little distortion. I am not sure of the generic position of the shell, but it appears to be nearest to Tylostoma or to Pterodonta, and it may not unlikely be the giant *Tylostoma* (*T. princeps*) which Dr. White has described from the mountains of Tehuacan (La Naturaleza, Mexico, 1883, p. 220). The casts (of *Pterodonta inflata?*) figured by Ramirez in his geological report on the Sierra Mojada mountains (Anales del Ministerio de Fomento, III, 1880) not impossibly represent the same species.

Ostrea *sp. indet.* (Plate XIII, fig. 8).

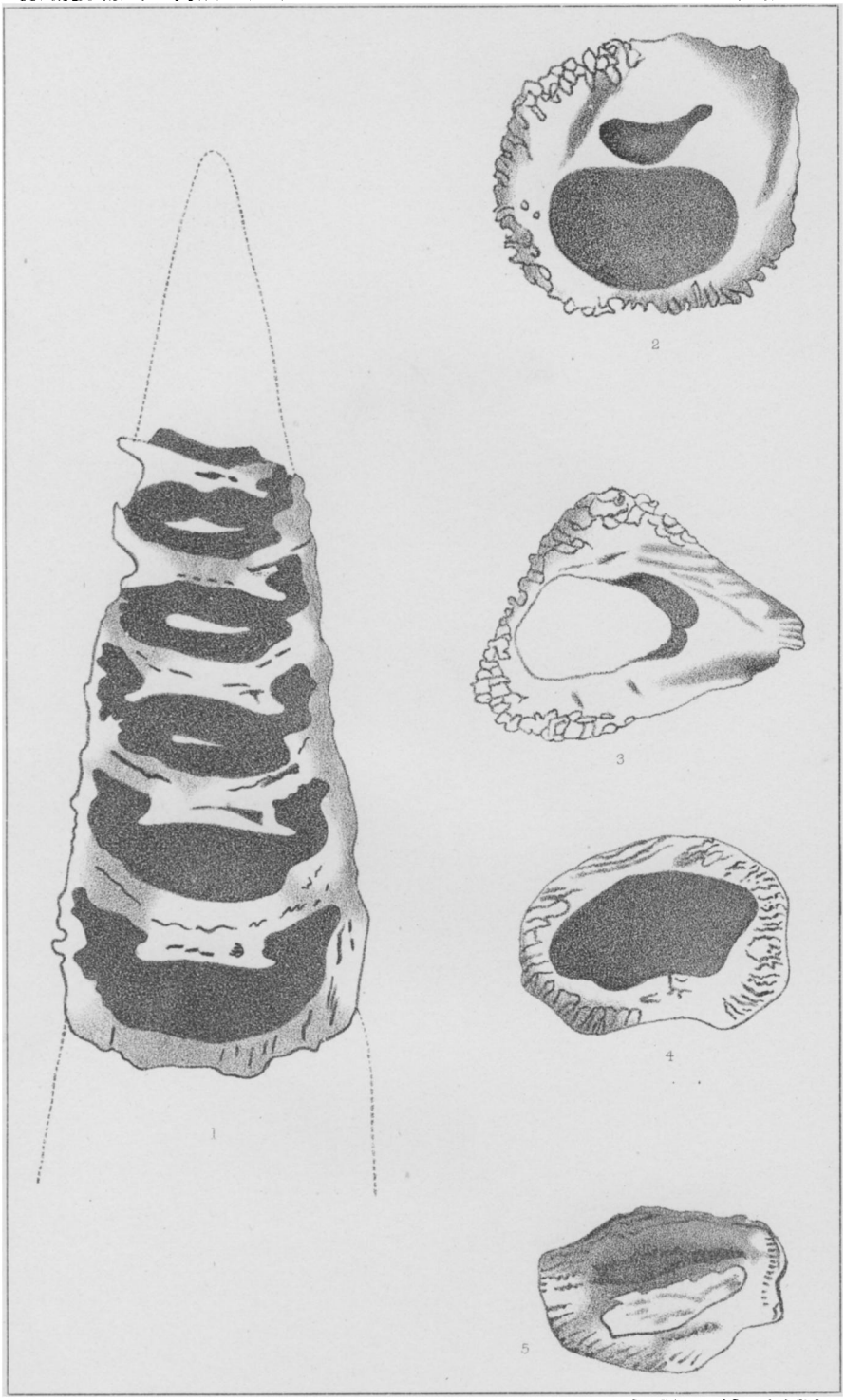
This is, without doubt, the oyster which has been referred to by Bárcena as *Ostrea* (*Exogyra*) *virgula.* It is certainly of the type of that species, but yet it may equally represent one of the closely related Cretaceous forms, and is, perhaps, not far removed from Gabb's *Gryphea mucronata* (*G. Pitcheri.*)

Caprina? (Plate XIII, fig. 7).

Ichthyosarcolithes? (Plate XII, figs. 2, 3, 4, 5).

Hippurites *sp. indet.* (Plate XIV).

This is by far the largest Hippurite which I found in the Mexican rocks. I strongly suspect that it is the common European *H. cornu-vaccinum,* but the condition of preservation of the specimen does not permit its specific affinities to be positively determined. The drawing is traced from a polished marble.



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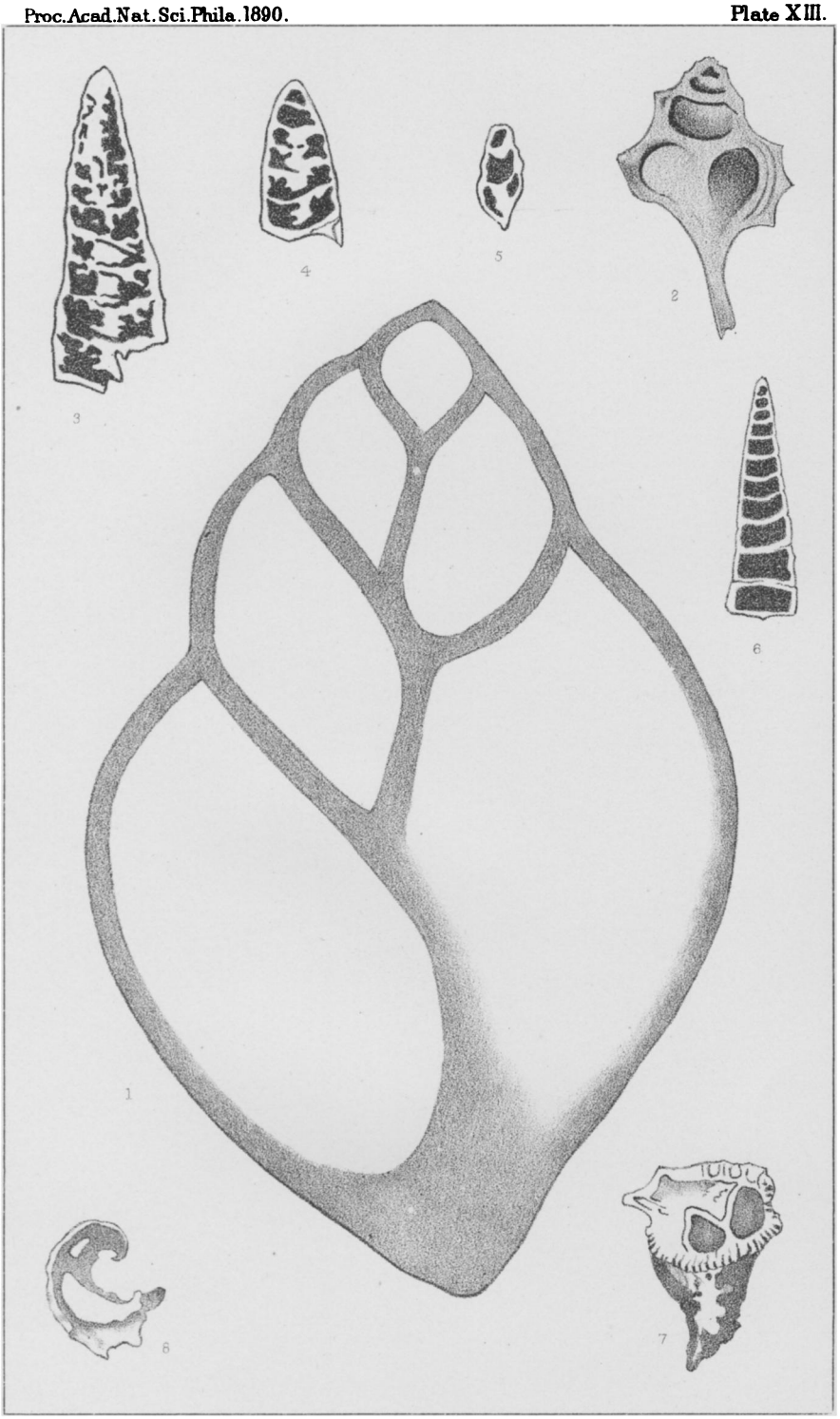

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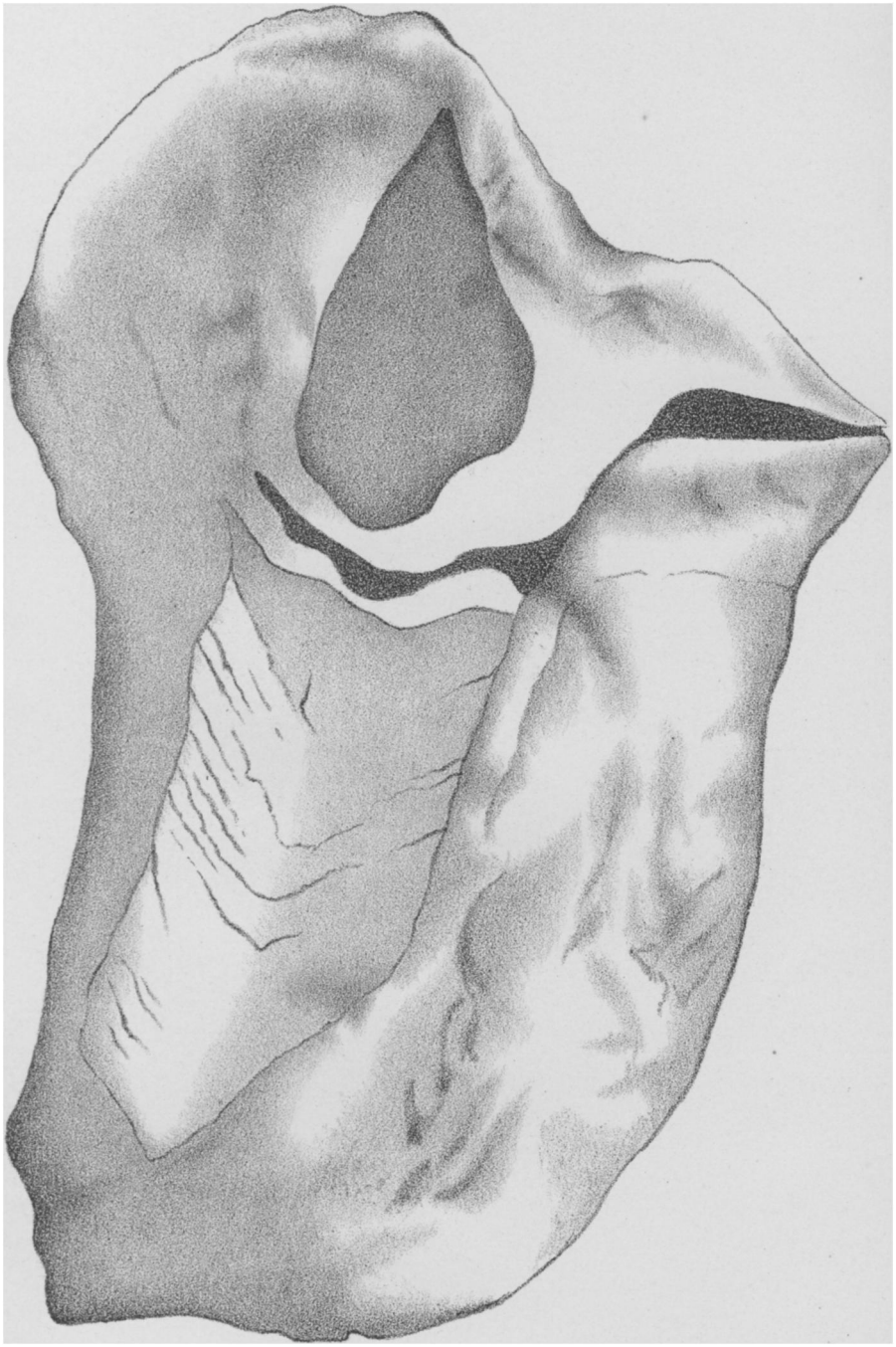

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